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# DESIGN AND ECONOMICS OF BITUMINOUS TREATED BASES IN TEXAS

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# Design and Economics of Bituminous Treated Bases in Texas

by

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## Introduction

The shortage of high quality aggregates together with increased traffic has created a need for treating local materials for use as base courses. Asphalt has become a common stabilizer during the last decade; however, the criteria developed for materials selection, design and construction techniques have been based mainly on requirements developed for asphalt concrete surface courses. Thus, because of these restrictive requirements, materials and construction techniques are being used which result in significant increases in costs and additionally provide a stabilized material whose structural properties exceed those required by the environment and imposed traffic.

This report deals with types of tests, test criteria and types of materials suitable for bituminous stabilization. A review of layer equivalency is included as well as current cost data for both stabilized and unstabilized base courses. The authors suggest that more effective use might be made of layer equivalencies from cited data in the report. This would allow the engineer to determine the types of local material that would be suitable for use in economical bituminous stabilized layers.

## Objectives

Objective of this Type B study was to investigate the current materials selection criteria, construction techniques and pavement design methods to provide an economical material to satisfy selected requirements of asphalt base courses.

## Summary Findings

### Mixture Characteristics

The engineer is faced with providing a bituminous stabilized mixture to satisfy the needs of a particular situation. Certainly these demands vary from construction project to construction project and are dependent upon such factors as environment, loading conditions and locations within the structural pavement section, among others. In an attempt to consider these factors the engineer must consider the following mixture characteristics and their relative importance for a particular use of the bituminous stabilized soil:

1. Stability
2. Durability
3. Fatigue behavior
4. Tensile behavior
5. Flexibility
6. Workability

Few tests have been developed to indicate the flexibility and workability of bituminous stabilized materials. Elongation and certain tensile tests are attempts to measure flexibility while gradation limits and compaction tests have been utilized to control workability.

## Test Methods

Specifications and criteria for bituminous stabilized soils are almost exclusively based on stability, durability and gradation requirements. A survey of state practices has been recently published by the Transportation Research Board. This survey indicates that the most widely used stability tests are the Hveem, Marshall, and unconfined compression tests. Other tests used for stability type determinations include Hubbard-Field, triaxial compression, repeated load triaxial, California "R" Value and various penetration type tests including the California Bearing Ratio, the Iowa Bearing Value and Florida Bearing Value.

Durability tests which have been utilized for control of bituminous stabilized mixtures include the California Moisture Vapor Susceptibility test, immersion compression test and the swell test.

TABLE 1. EMPIRICAL GUIDES FOR SOIL, SAND AND GRANULAR MATERIALS QUALIFICATION AND STABLIZATION

| Sieve Analysis | Soil Bitumen, † % | Sand Bitumen, % | Waterproofed Granular Stabilization, % | | |
|---|---|---|---|---|---|
| Passing | | | A | B | C |
| 1 1/2-in. | . . . | . . . | 100 | | |
| 1-in. | ‡ | . . . | 80-100 | 100 | |
| 3/4-in. | . . . | . . . | 65-85 | 80-100 | 100 |
| No. 4 | >50 | 100 | 40-65 | 50-75 | 80-100 |
| No. 10 | . . . | . . . | 25-50 | 40-60 | 60-80 |
| No. 40 | 35-100 | . . . | 15-30 | 20-35 | 30-50 |
| No. 100 | . . . | . . . | 10-20 | 13-23 | 20-35 |
| No. 200 | 10-50 | <12; <25 § ‖ | 8-12 | 10-16 | 13-30 |
| Characteristics of Fraction Passing No. 40 Sieve | | | | | |
| Liquid limit | <40 | . . . | . . . | . . . | . . . |
| Plasticity index | <18 | . . . | <10; <15 | <10; <15 | <10 <15 ¶ |
| Field moisture equiv. | . . . | <20 § | . . . | . . . | . . . |
| Linear shrinkage | . . . | <5 § | . . . | . . . | . . . |

† Proper or general.

‡ Maximum size not larger than 1/3 of layer thickness; if compacted in several layers, not larger than thickness of one layer.

§ Lower values for wide and higher values for narrow gradation band of sand. If more than 12% passes the No. 200 sieve, restrictions are placed as indicated on field moisture equivalent and linear shrinkage.

‖ A certain percentage of -200 or filler material is indirectly required to pass supplementary stability test.

¶ Values between 10 and 15 permitted in intermediate gradings.

TABLE 2. GRADING AND PLASTICITY REQUIREMENTS FOR SOIL-BITUMEN MIXTURES

| Sieve Size | Percent Passing |
|---|---|
| No. 40 | 50 - 100 |
| No. 200 | 0 - 35 |
| **Atterberg Limits** | **Maximum Value** |
| Liquid limit | 30 |
| Plasticity index | 10 |

The majority of bituminous soil stabilization has been performed with asphalt cement, cutback asphalt and asphalt emulsion. Current design and construction trends, particularly in the state highway departments, have indicated that stabilization of base courses with asphalt cements is by far the most popular form of bituminous stabilization. In general, those materials which are most effectively stabilized with asphalt cement have lower percentages of fines than those materials which have been stabilized with cutback asphalt and emulsion.

## Gradation Requirements

Some of the earliest criteria for bituminous stabilization were developed by the Highway Research Board Committee on Soil-Bituminous Roads. These criteria were revised and published by Winterkorn and appear in Table 1. The American Road Builders Association made similar recommendations and these are shown in Table 2.

TABLE 3. ENGINEERING PROPERTIES OF MATERIALS SUITABLE FOR BITUMINOUS STABILIZATION

| % Passing Sieve | Sand-Bitumen | Soil-Bitumen | Sand-Gravel-Bitumen |
|---|---|---|---|
| 1-½″ | | | 100 |
| 1″ | 100 | | |
| ¾″ | | | 60-100 |
| No. 4 | 50-100 | 50-100 | 35-100 |
| 10 | 40-100 | | |
| 40 | | 35-100 | 13-50 |
| 100 | | | 8-35 |
| 200 | 5-12 | good - 3-20<br>fair - 0-3 and 20-30<br>poor - > 30 | 0-12 |
| Liquid Limit | | good - < 20<br>fair - 20-30<br>poor - 30-40<br>unusable - > 40 | |
| Plasticity Index | <10 | good - 5<br>fair - 5-9<br>poor - 9-15<br>unusable - > 12-15 | <10 |

Includes slight modifications later made by Herrin.

The Asphalt Institute grading and plasticity requirements for bituminous base course specifications require:

1. Less than 25 percent passing the No. 200 sieve,
2. Sand equivalent not less than 25, and
3. Plasticity index less than 6.

Herrin has presented and revised a table (Table 3) recommending suitable soils for stabilization by bituminous materials. Contained in this table are recommendations on the suitability of various soils with certain percentages of minus No. 200 material, and certain liquid limit and plasticity index ranges.

Certain limits have been developed by the Asphalt Institute's Pacific Coast Division, Chevron Asphalt Company and Dougles Oil Company for emulsion treated materials. The requirements recommended by the Asphalt Institute (Table 4) suggest that the percent of minus No. 200 material should be in a range of 3-15 percent, the plasticity index should be less than 6, and the product of the plasticity index and the percent passing the No. 200 sieve should not exceed 60. The Chevron Asphalt Company has presented criteria (Table 5) which indicate that the California sand equivalent test should be used as a measure of the plasticity requirements for the soil and should have a minimum value of 30. Up to 25 percent passing the No. 200 sieve is allowed for the material identified as silty sand.

TABLE 4. GRADING, PLASTICITY AND ABRASION REQUIREMENTS FOR SOILS SUITABLE FOR EMULSIFIED ASPHALT TREATED BASE COURSE

| | Percent Passing by Weight | | |
|---|---|---|---|
| Sieve Size | 2 inch maximum | 1-1/4 inch maximum | 3/4 inch maximum |
| 2-1/2 inch | 100 | | |
| 2 inch | 90-100 | 100 | |
| 1-1/2 inch | | 90-100 | |
| 1 inch | | | 100 |
| 3/4 inch | 50-80 | 50-80 | 80-100 |
| No. 4 | 25-50 | 25-50 | 25-50 |
| No. 200 | 3-15 | 3-15 | 3-15 |

Other Requirements

a. Plasticity Index, 6 maximum.
b. Resistance Value, 75 minimum.
c. Loss in Los Angeles Abrasion Machine, 50 percent maximum.
d. Product of Plasticity Index and the percent passing the No. 200 sieve shall not exceed 60.

TABLE 5. TYPICAL AGGREGATES SUITABLE FOR TREATMENT WITH EMULSIFIED ASPHALTS

| Category | ASTM Test Method | Processed* Dense Graded Aggregates | SANDS | | | Semi-Processed Crusher, Pit or Bank Run Aggregates |
|---|---|---|---|---|---|---|
| | | | Poorly Graded | Well Graded | Silty Sands | |
| Gradation: 1½" | | 100 | | | | 100 |
| % Passing 1" | | 90-100 | | | | 80-100 |
| ¾" | | 65-90 | | | | — |
| ½" | | — | 100 | 100 | 100 | — |
| # 4 | | 30-60 | 75-100 | 75-100 | 75-100 | 25-85 |
| 16 | C-136 | 15-30 | — | 35-75 | — | — |
| 50 | | 7-25 | — | 15-30 | — | — |
| 100 | | 5-18 | — | — | 15-65 | — |
| 200 | | 4-12 | 0-12 | 5-12 | 12-25 | 3-15 |
| Sand Equivalent, % | D-2419 | 30 Min. | 30 Min. | 30 Min. | 30 Min. | 30 Min. |
| Plasticity Index | D-424 | — | NP | NP | — | — |
| Untreated Resistance R Value | ** | 78 Min. | 60 Min. | 60 Min. | 60 Min. | 60 Min. |
| Los in Los Angeles Rattler (after 500 revolutions) | C-131 | 50 Max. | — | — | — | 60 Max. |

*Must have at least 25% Crush Count.
**See AASHO T-174, T-175, and T-176.

The report also presents an extensive review of the literature covering such items as mix stability and durability, selection of the type and quantity of bitumen and temperature for laboratory and field measurements of mixture properties. Recommendations are made regarding reasonable test temperatures as this parameter may vary from region to region.

## Layer Equivalency

The concept of layer equivalencies has been in use for a number of years by several agencies. The concept most often advanced is that of equating different types of roadbuilding materials in terms of equivalent thickness in a structural section. In the case of layer equivalencies for base courses, it is often the practice to express layer equivalencies in terms of equivalent thicknesses of granular base course. For example, the Asphalt Institute suggests that a 2 to 1 layer equivalency exists between granular base and hot mixed bituminous stabilized base. This statement implies that 1 inch of asphalt stabilized material will replace 2 inches of granular material assuming certain boundary conditions are satisfied.

The development of appropriate layer equivalencies has been a subject of a number of research projects. The general conclusion reached by these investigators is that a variety of methods exist to establish equivalencies for specific materials and specific pavement sections. These methods can also be used for general cases provided the investigator realizes that equivalencies generated will depend on:

1. Wheel load and contact pressure,
2. Stiffness characteristics of the particular material.
3. Stiffness characteristics of other materials in the structural section,
4. Subgrade characteristics,
5. Thickness of the various components of the structural sections, and
6. Position of the material in the structural section.

A new pavement design being implemented in Texas has the ability to consider the supporting capacity of bituminous stabilized materials. The performance equation utilized in this system has been used to develop layer equivalencies which are included in Table 6.

TABLE 6. LAYER EQUIVALENCIES AS DETERMINED BY TEXAS HIGHWAY DEPARTMENT FLEXIBLE PAVEMENT DESIGN METHODS*

| Temperature Constant | Total Traffic, Eq. 18 Kip Axle Loads X $10^6$ | Subgrade Stiffness Coefficient | | | |
|---|---|---|---|---|---|
| | | 0.15 | 0.20 | 0.25 | 0.30 |
| | 1 | 2.3 | 2.4 | 2.4 | 2.5 |
| 9 | 3 | 2.6 | 2.8 | 2.9 | 3.1 |
| | 6 | 3.3 | 3.7 | 3.8 | 4.2 |
| | 10 | --- | | --- | --- |
| | 1 | 2.2 | 2.3 | 2.4 | --- |
| 25 | 3 | 2.3 | 2.4 | 2.5 | 2.5 |
| | 6 | 2.5 | 2.6 | 2.7 | 2.8 |
| | 10 | 2.8 | 2.9 | 3.1 | 3.2 |
| | 1 | 2.1 | 2.1 | --- | --- |
| 38 | 3 | 2.3 | 2.3 | 2.3 | --- |
| | 6 | 2.4 | 2.5 | 2.6 | 2.8 |
| | 10 | 2.5 | 2.7 | 2.8 | 3.1 |

*Layer Equivalencies assume the stiffness coefficient of untreated base is 0.50 and treated base is 1.00.

## Economic Comparison

A valid economic comparison of alternate base course materials must be made on both initial cost and maintenance cost. Since little reliable maintenance cost information is presently available, this report compares the economics of base courses on initial cost only.

A review of the component production cost of hot mix has suggested that materials cost has been a rather large portion of the cost of bituminous treated materials, thus, investigating materials with lower prices than those materials conventionally utilized appears promising. The price of asphalt has doubled during the last 12 months and thus has assumed a somewhat larger proportion of the component cost of hot mixed bituminous materials. Cost savings thus must be effected by reducing the amount of asphalt.

Aggregate costs have escalated about 50 percent in the last 12 months. Alternate sources of aggregates such as sands appear to be promising in many areas of Texas as substitutes for the conventional black base aggregates. Other "marginal materials" (as defined by present specifications criteria) should be investigated for potential utilization.

Dryer drum mixing operations are becoming more popular for jobs requiring large tonnages of hot mixed bituminous materials.

The potential cost saving by use of this type of equipment should be between fifty cents to one dollar per ton. Other types of mixing, transport and laydown equipment should be investigated with the hope of reducing these non-materials costs.

In summary, a number of mixture characteristics must be considered to properly evaluate bituminous treated mixtures including stability, durability, fatigue behavior, tensile behavior, flexibility and workability. Ideally a single test would provide sufficient information, however, such a test has not been developed nor is there hope for such a test in the near future. Thus, it appears as if a number of tests must be considered to adequately define mixture characteristics.

Test geometry and loading conditions of the ideal test must be such that they represent the state of loading encountered in the field by the mixture. Certainly the state of stress in the field is biaxial if not triaxial while the load is repeated and of varying magnitude and duration. Research has indicated that a testing apparatus to perform such a test and the theory necessary to interpret such test results are complex and in the near future will not be practical for everyday use. Thus, less complex tests must be considered and their results correlated with in-service performance of pavements.

Basically the engineer would prefer a test to be suitable for construction control and mixtures evaluation as will as for utilization in pavement design procedures to determine layer thickness. Thus, it is important that the procedure have the capability to delineate between an acceptable and unacceptable mixture for all of these purposes.

Those materials most suitable for bituminous stabilization have been defined. The gradations and Atterberg Limits suggested by Herrin (Table 3) appear to be reasonable. The utilization of the sand equivalent test together with Atterberg Limits and sieve analyses should be used as the preliminary criteria for acceptance of mixture based on laboratory testing. Criteria for acceptance of mixture based on laboratory testing need to be further defined for bituminous stabilized materials. Testing temperatures as well as acceptance criteria should be established for existing tests as well as any developed tests based on field performance.

The concept of layer equivalency ideally should be applied to industrial projects as the layer equivalency is dependent on wheel load and contact pressure, stiffness characteristics of the particular material, stiffness characteristics of other materials in the structural section, subgrade characteristics, thickness of the various components of the structural sections and position of the material in the structural section. Typical equivalencies of black base as determined from the literature review is 2:1.

Initial work in the follow-on study resulting from this Type B study will investigate alternative testing techniques in order to best define the requirements of a test method as described above. The review of the test method presently being untilized in this paper will be used as background data with some type of repeated load test appearing to be most desirable.

## Implementation Statement

Material is included in the report which allows the engineer to determine the types of materials that can be utilized for bituminous stabilized layers. Current test methods and test criteria are reviewed which allow for determination of bitumen contents. Layer equivalencies and cost data are included for typical types of bituminous stailization. Use of the above information will provide more economical bituminous treated base courses.

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